Silicon photodiode characterization
Electrical measurements
Procedure
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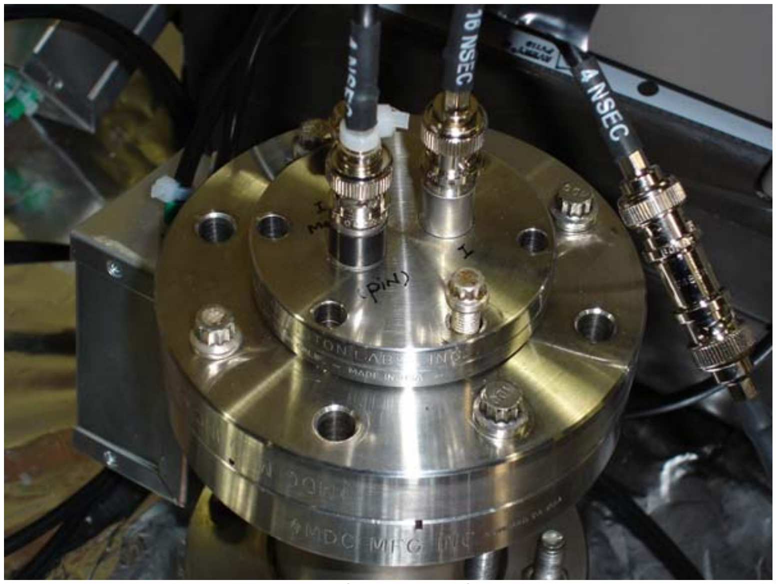
## Motivation.

Silicon photodiodes (SPDs), despite having 2-4 orders of magnitude higher responsivity than other x-ray detectors are subject to other problems and must be characterized electrically before becoming a useful diagnostic. They are also quite sensitive to visible light and therefore the electrical tests must occur in a completely dark environment.

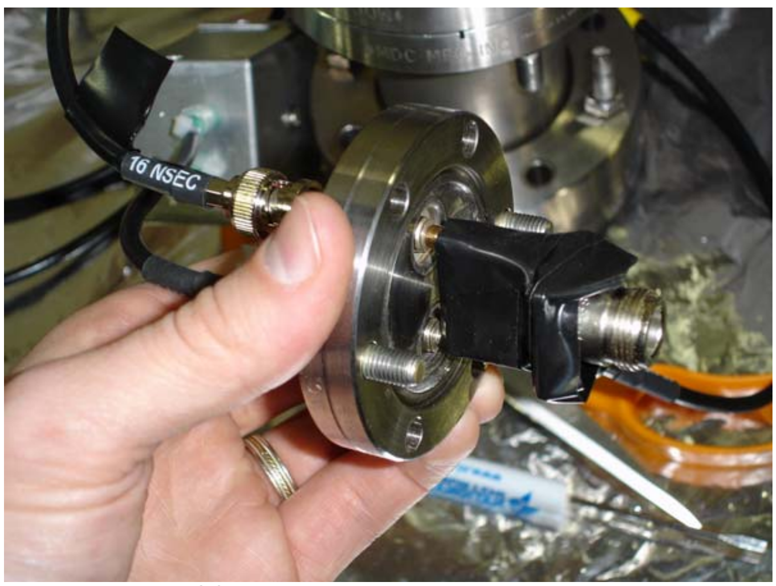
The operation of SPDs in current mode (continuous ammeter measurement) subjects them to susceptibility to ambient electronic noise and ground loops. In order for the ammeter (electrometer) to accurately measure the photocurrent down to the required <1 pA level with the Keithley 617/6514/6517 ammeters, the SPD must have a source impedance of 200 MΩ (0.2 GΩ) or greater. This requirement is stated in the electrometer vendor’s documentation, and is a result of the “burden voltage” limitation (it will vary among different current range scales, models and manufacturers). Typical burden voltages for the ammeters which we maintain at the beamlines are in the 0.1-1.0 mV range. If the diode’s source impedance (also called “shunt resistance”, abbreviated $R_{sh}$) is low, the diode will show a nonzero current even in a dark environment. Thus, high “dark current” may be symptomatic of a lower than desired shunt resistance. This document describes the equipment and procedures used to electrically validate new photodiodes in terms of dark current and shunt resistance.

## Equipment needed.

(test setup)

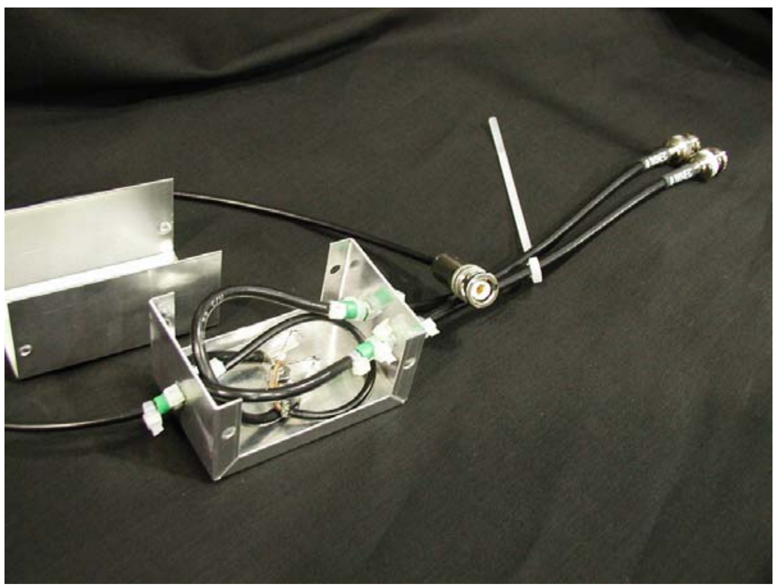


(dark box feedthrough flange)



(BNC feedthrough / n-connector, inside dark box)

(K 6172 adapter)



(triax-coax breakout assembly, open)

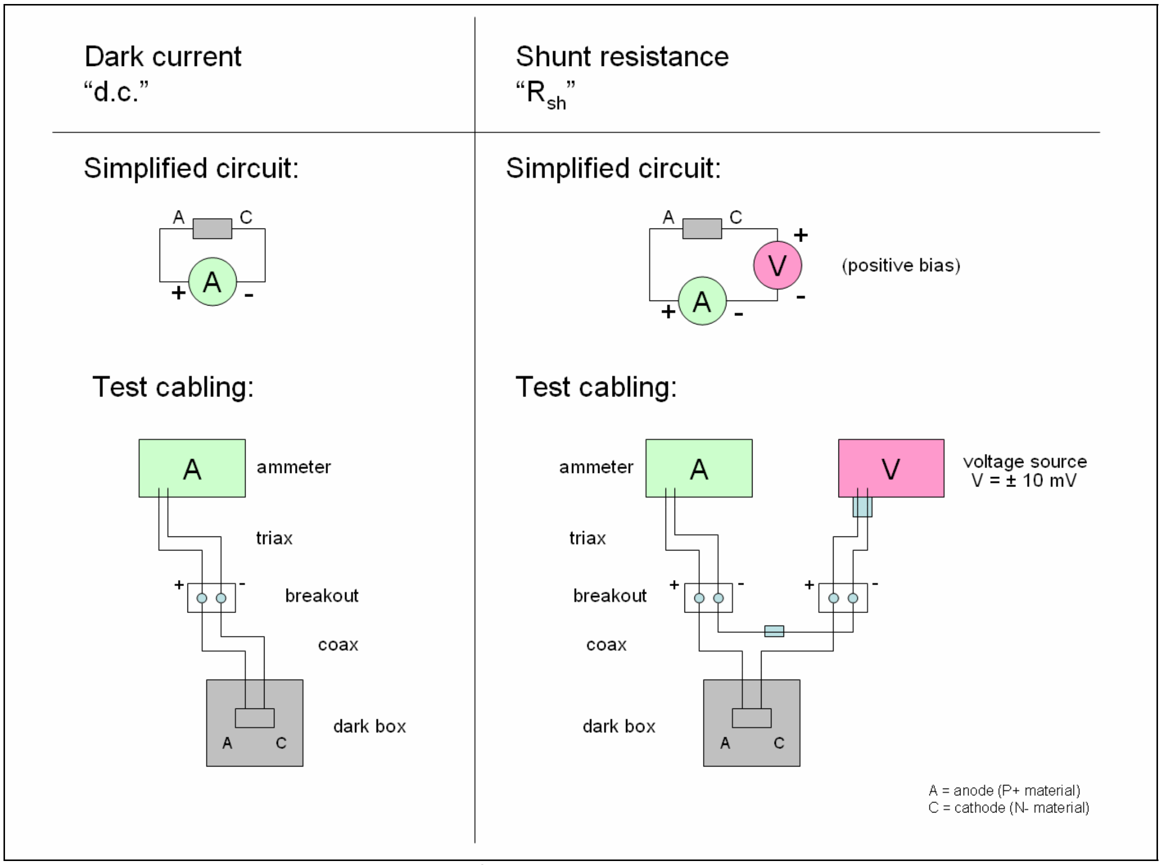
The complete setup is shown in the photos above. It consists of:

1. A “dark box”. For this we use a 4½“ conflat nipple, blanked on the bottom and providing 2 isolated leads on the top (2 BNC feedthroughs on a 2¾“ flange). The feedthrough flange is sealed against the 4½“ nipple with a rubber (viton) gasket. On the inner side of the feedthrough flange a female n-connector is mounted. This is designed to receive n-connector AXUV holders. The AXUV holder must be screwed onto the female receptacle carefully to avoid loosening the contact between the receptacle and the feedthroughs. Although the n-connectors and AXUV holder outer surface is in direct electrical contact with the SPD cathode, it should not make contact with the wall of the dark box but is isolated by air inside the

box and by dielectric insulator at the feedthrough. The anode feedthrough is marked with black tape.

2. AXUV n-connector holder (male). These are made to hold AXUVs semi-permanently. They may be available from STL, LANL, or beamline staff. These holder assemblies include a cover plate so there should be little risk of physical damage to the diode once it is installed to the holder. However, to use the cover, the AXUV leads must be clipped. In many cases it may be preferable to keep the leads long, so a cover is not used for the electrical test (see procedure below).
3. Keithley electrometer (model 6514, 6517A, or 617). The ammeter function of one of these instruments is used to measure current in the pA scale.
4. Keithley calibrated source model 263. This is used to provide ± 10 mV bias during shunt resistance measurement. Note the cabling requires 3-lug triax connectors whereas this instrument has 2-lug connector type. Thus, an adapter is required (called out below)
5. (2-lug male triax to 3-lug female triax, Keithley model 6172).
6. Two (2) triax-BNC breakout assemblies. Two of these have been built by the beamline staff specifically for AXUV diagnostics and consists of a small aluminum breakout box, feeding three connectorized cables. In the breakout box, the two inner conductors of a (3-lug) triax cable are separated onto two independent BNC cables, with the outer conductor common to the chassis. The BNC cable carrying the potential of the inner triax conductor is indicated with tape or cable tie, indicating the “high” side of the breakout.
7. BNC female-female adapter (“barrel”, Keithley CS-565). This is used to connect BNC cables from the two breakout assemblies together when $R_{sh}$ is measured.

## Cabling, Test Setup, and Data Collection Procedure.




(cabling for dc and $R_{sh}$ measurements)

Procedure (refer to cabling diagrams)

1. Install the AXUV holder to the n-connector mount on the dark box feedthrough flange. Be sure to keep the cover on the holder, in order to ensure protection of the diode from possible handling damage. Note: the leads must be clipped in order to allow the holder cover to be attached; however, clipping the leads may make it difficult to install the diode to the test chamber as a reference diode. For this reason it may be preferable to keep the leads long, and allow the SPD to project from the n-connector (don't use cover) during testing. For SPDs which are permanently installed to n-connectors (reference diodes), clipping the leads is OK. Also note: AXUV diodes cover from IRD with glass cover. It is preferable to keep this cover in place during electrical testing so as not to risk damage to the SPD active surface. The SPD anode should be wired to the center pin of the n-connector. On the AXUV, this can be identified by a notch on the AXUV ceramic and a large solder blob or wide-spaced leads on the diode itself. When a healthy SPD is installed properly, current will be positive with ambient light illumination (see step 4).
2. With the test flange in place (on the dark box), verify the isolation of each diode lead from the dark box chassis (test flange). Use a multimeter (DMM) in resistance mode with beep to verify there is no connection

between anode and the dark box chassis (test flange), and between cathode and the dark box chassis (use the outside connector on feedthrough). DO NOT CONNECT THE DMM ACROSS THE DIODE! If either of these tests fails, stop here and fix the problem before proceeding. You should not have any shorts if you are operating on a flat surface.

3. Set up the cabling for dark current measurement.
4. Before tightening the 2 bolts on the top of the dark box, verify that the ammeter sees a difference between AXUV holder held out of the box (high positive current) and AXUV inserted into the box (low current). The AXUV holder cover may need to be loosened in order to see this light leakage effect. The purpose of this step is to verify basic functionality of the SPD and polarity of the cabling. Adjustments to the test and/or AXUV holder assembly may need to be made at this point if verification fails. Typical signals are 1-10 pA with feedthrough inserted and 1-10 nA with it open 1-2 inches (with no holder cover in place)
5. Tighten the AXUV holder cover to the AXUV holder and insert the flange into the dark box. Tighten the 2 bolts with your fingers, ensuring that the rubber (viton) gasket is placed properly so that the box is completely light tight.
6. Measure the current using the ammeter. This is the dark current. Wait at least 10 seconds after adjusting cables or enabling the ammeter (turning off zero-check) before recording the current. The current should be stable over several seconds. You may need to wait as long as a minute or two for the dark current to settle out completely (this is most important for high impedance / high capacitance diodes). A stable result can be defined as a current which is constant within 0.01 pA for 30 seconds or more. For some diodes, the dark current may be negative at first and then drift positive. If the dark current is negative even after several minutes, then the value should be recorded with its sign. Be sure to record any instability in the apparent dark current (if the current appear to jump around). Dark current is typically reported in picoAmperes (pA) and ranges from 0.01 for a good diode to 100 pA to a poor one.
7. Switch the ammeter to zero-check (disable). Set the voltage value to +10 mV and set it into standby mode (disable). Set up the cabling for shunt resistance measurement.
8. Once the $R_{sh}$ cabling is verified, switch the voltage source to operate, then turn zero-check off on the ammeter, and observe the diode current under +10 mV bias. The current should be positive, and may take a minute or so to settle out. If the current is negative even after several minutes, then the value should be recorded with its sign. Be sure to record any instability in the apparent current (if the current appear to jump around). The magnitude of the biased current is typically reported in picoAmperes (pA) and ranges from 1 for a good diode to 5000 pA to a poor one.
9. Switch the polarity of the source with the “+/-“ button supplied on the 263 front panel so that -10 mV is applied. Observe the diode current under +10 mV bias. The current should be negative, and may take a minute or

so to settle out. If the current is positive even after several minutes, then the value should be recorded with its sign. Be sure to record any instability in the apparent current (if the current appear to jump around). The magnitude of the biased current is typically reported in picoAmperes (pA) and ranges from 1 for a good diode to 5000 pA to a poor one.

10. The shunt resistance can be estimated from the following equation: $R_{sh} = \frac{\left|\frac{10}{I_{+10}}\right| + \left|\frac{10}{I_{-10}}\right|}{2}$. For current values in pA and bias values in mV, the resultant shunt resistance $R_{sh}$ will be reported in gigaOhms (GΩ). Typical values range from 3.0 GΩ for a good diode to 0.005 GΩ from a poor one. Record the diode serial number, dark current, 10 mV positive bias current, 10 mV negative bias current, and shunt resistance and keep this information with the diode.